

Supplementary information

Respiratory Virus Shedding in Exhaled Breath and Efficacy of Face Masks

Nancy HL Leung, Daniel KW Chu, Eunice YC Shiu, Kwok-Hung Chan, James J McDevitt, Benien JP Hau, Hui-Ling Yen, Yuguo Li, Dennis KM Ip, JS Malik Peiris, Wing-Hong Seto, Gabriel M Leung, Donald K Milton, Benjamin J Cowling

Table of Contents

Supplementary discussion points2

Supplementary tables4

Supplementary discussion points

We identified viral shedding in respiratory droplets and aerosols for coronavirus, influenza virus and rhinovirus, confirming that both respiratory droplets and aerosols could be potential modes of transmission for these infections. In addition, we showed that surgical face masks can effectively block the dissemination of coronavirus and influenza virus into the environment in exhaled breath droplets, and can even block the dissemination of common human coronaviruses into the environment in exhaled breath aerosols. Our findings provide mechanistic evidence to support the use of surgical face masks for symptomatic cases as a source control for coronavirus and influenza virus transmission.

The difference in the filtration efficiencies of the three viruses by surgical masks may suggest the size distribution of virus-laden respiratory droplets vary for different respiratory viruses. For example, the exhaled virus-containing particles might be smaller for participants with influenza virus compared to coronavirus infections, which might signal a higher potential for aerosol transmission for influenza. The size of exhaled particles depends on the site of their origin (upper respiratory tract, lower respiratory tract or alveolar regions) in the lungs¹. The sizes of particles that contain both viruses are unknown, but existing studies indicate that fine particles ($<1\mu\text{m}$) released by influenza patients may dominate². It is perhaps surprising that we observed no effect of face masks on dissemination of rhinovirus in respiratory droplets (Table 1b), given that the surgical mask was able to block virus in respiratory droplets for influenza virus in the present and previous study³, and for coronavirus in the present study. It has been suggested that surgical face masks as source control reduce the exposure at the receiver by both filtration, where exhaled particles are captured by the mask, and by deflection, where exhaled particles are not captured by the mask but are deflected away from the receiver via the leakage around the edges of the surgical face mask^{4,5}. Particles as large as $30\mu\text{m}$ have been shown to be able to escaped by deflection⁶. It may be possible that rhinovirus was more common in smaller droplets just above the $5\mu\text{m}$ cut-off, and these were not blocked by the surgical mask but were captured by the $5\mu\text{m}$ impactor and classified as respiratory droplets. Further experiments could help to explain this phenomenon, especially on the droplet generation for different respiratory virus infections and during different stages of infection or illness, where such data are minimal at present⁷.

Our study only included symptomatic individuals, and seasonal coronavirus RNA was not identified from respiratory droplets or aerosols of the small number of infected individuals who did not cough, suggesting that for seasonal coronaviruses the aerosols were primarily generated in the proximal airways via shear forces and likely in the 2 to $4\mu\text{m}$ size range. If this suggested only minimal shedding in exhaled breath in individuals without symptoms, use of hand hygiene would be more effective in reducing the pre-symptomatic or asymptomatic transmission of SARS-CoV-2. On the other hand, if distal small airway reopening events contribute to aerosol generation and viral load in fine aerosols in SARS-CoV-2 infection with evidence of pulmonary involvement, especially in the absence of cough, the viral aerosols might be in the submicron size range and behave more like influenza virus than the seasonal human coronaviruses.

Additional references

- 1 Wei, J. & Li, Y. Airborne spread of infectious agents in the indoor environment. *Am. J. Infect. Control* **44**, S102-108, doi:10.1016/j.ajic.2016.06.003 (2016).
- 2 Fabian, P. *et al.* Influenza virus in human exhaled breath: an observational study. *PLoS One* **3**, e2691, doi:10.1371/journal.pone.0002691 (2008).

- 3 Milton, D. K., Fabian, M. P., Cowling, B. J., Grantham, M. L. & McDevitt, J. J. Influenza virus aerosols in human exhaled breath: particle size, culturability, and effect of surgical masks. *PLoS Pathog.* **9**, e1003205, doi:10.1371/journal.ppat.1003205 (2013).
- 4 Diaz, K. T. & Smaldone, G. C. Quantifying exposure risk: surgical masks and respirators. *Am. J. Infect. Control* **38**, 501-508, doi:10.1016/j.ajic.2010.06.002 (2010).
- 5 Mansour, M. M. & Smaldone, G. C. Respiratory source control versus receiver protection: impact of facemask fit. *J. Aerosol Med. Pulm. Drug Deliv.* **26**, 131-137, doi:10.1089/jamp.2012.0998 (2013).
- 6 Ha'eri, G. B. & Wiley, A. M. The efficacy of standard surgical face masks: an investigation using "tracer particles". *Clin. Orthop. Relat. Res.*, 160-162 (1980).
- 7 Fabian, P., Brain, J., Houseman, E. A., Gern, J. & Milton, D. K. Origin of exhaled breath particles from healthy and human rhinovirus-infected subjects. *J. Aerosol Med. Pulm. Drug Deliv.* **24**, 137-147, doi:10.1089/jamp.2010.0815 (2011).

Supplementary tables

Supplementary Table 1. Characteristics of individuals with symptomatic coronavirus, influenza virus or rhinovirus infection, stratified by respiratory droplets and aerosols collected while not wearing or wearing a surgical face mask. Seasonal coronavirus (n = 17), seasonal influenza virus (n = 43) and rhinovirus (n = 54) infection were confirmed in individuals with acute respiratory symptoms by RT-PCR in any samples (nasal swab, throat swab, respiratory droplets and aerosols) collected. A subset of participants provided exhaled breath samples for both mask intervention (coronavirus, n = 4; influenza virus, n = 8; rhinovirus, n = 14).

	All who provided exhaled breath (n = 246) n (%)	Coronavirus		Influenza virus		Rhinovirus	
		Without mask (n = 10) n (%)	With mask (n = 11) n (%)	Without mask (n = 23) n (%)	With mask (n = 28) n (%)	Without mask (n = 36) n (%)	With mask (n = 32) n (%)
Female	144 (59)	8 (80)	8 (73)	12 (52)	14 (50)	20 (56)	17 (53)
Age group (in years)							
11-17	12 (5)	0 (0)	0 (0)	3 (13)	5 (18)	2 (6)	2 (6)
18-34	114 (46)	6 (60)	6 (55)	5 (22)	8 (29)	17 (47)	13 (41)
35-50	79 (32)	1 (10)	1 (9)	9 (39)	11 (39)	11 (31)	12 (38)
51-64	35 (14)	2 (20)	4 (36)	6 (26)	4 (14)	3 (8)	4 (12)
≥ 65	6 (2)	1 (10)	0 (0)	0 (0)	0 (0)	3 (8)	1 (3)
Chronic medical conditions							
Any	49 (20)	3 (30)	3 (27)	1 (4)	5 (18)	7 (19)	5 (16)
Respiratory	18 (7)	0 (0)	0 (0)	1 (4)	4 (14)	1 (3)	2 (6)
Influenza vaccination							
Ever	94 (38)	3 (30)	4 (36)	8 (35)	12 (43)	13 (36)	13 (41)
Current season	23 (9)	1 (10)	1 (9)	1 (4)	1 (4)	3 (8)	3 (9)
Prior season only	71 (29)	2 (20)	3 (27)	7 (30)	11 (39)	10 (28)	10 (31)
Ever smoker	31 (13)	0 (0)	1 (9)	3 (13)	3 (11)	3 (8)	4 (12)
Time since illness onset, hours							
<24	22 (9)	0 (0)	0 (0)	2 (9)	3 (11)	2 (6)	1 (3)
24-48	100 (41)	6 (60)	5 (45)	6 (26)	9 (32)	14 (39)	14 (44)
48-72	85 (35)	4 (40)	6 (55)	13 (57)	10 (36)	13 (36)	13 (41)
72-96	39 (16)	0 (0)	0 (0)	2 (9)	6 (21)	7 (19)	4 (12)
History of measured fever ≥37.8°C	58 (24)	1 (10)	2 (18)	9 (39)	12 (43)	6 (17)	5 (16)
Measured fever ≥37.8°C at presentation	36 (15)	0 (0)	2 (18)	10 (43)	12 (43)	1 (3)	2 (6)
Measured body temperature (°C) at enrolment (Mean, SD)	36.8 (0.8)	36.5 (0.5)	37.2 (0.9)	37.4 (0.9)	37.4 (1)	36.6 (0.7)	36.5 (0.7)
Symptoms at presentation							
Feverishness	111 (45)	3 (30)	8 (73)	13 (57)	19 (68)	10 (28)	9 (28)
Cough	198 (80)	9 (90)	9 (82)	21 (91)	26 (93)	30 (83)	26 (81)
Sore throat	211 (86)	9 (90)	9 (82)	17 (74)	20 (71)	33 (92)	29 (91)
Runny nose	200 (81)	10 (100)	11 (100)	18 (78)	26 (93)	32 (89)	27 (84)
Headache	186 (76)	8 (80)	8 (73)	14 (61)	21 (75)	23 (64)	25 (78)
Myalgia	176 (72)	6 (60)	8 (73)	17 (74)	20 (71)	22 (61)	23 (72)
Phlegm	176 (72)	3 (30)	6 (55)	19 (83)	21 (75)	28 (78)	25 (78)
Chest tightness	64 (26)	0 (0)	3 (27)	5 (22)	10 (36)	4 (11)	9 (28)
Shortness of breath	103 (42)	4 (40)	4 (36)	6 (26)	10 (36)	18 (50)	13 (41)
Chills	100 (41)	3 (30)	6 (55)	15 (65)	20 (71)	11 (31)	9 (28)
Sweats	95 (39)	2 (20)	4 (36)	7 (30)	15 (54)	11 (31)	15 (47)
Fatigue	218 (89)	10 (100)	10 (91)	20 (87)	26 (93)	30 (83)	30 (94)
Vomiting	19 (8)	1 (10)	1 (9)	2 (9)	4 (14)	1 (3)	1 (3)
Diarrhea	17 (7)	1 (10)	1 (9)	1 (4)	1 (4)	3 (8)	3 (9)
Number of cough during exhaled breath collection (Mean, SD)	8 (14)	12 (24)	14 (29)	10 (12)	9 (11)	6 (10)	4 (4)

Supplementary Table 2. Efficacy of surgical face masks in reducing respiratory virus frequency of detection and viral shedding in respiratory droplets and aerosols of symptomatic individuals with coronavirus NL63, coronavirus OC43, coronavirus HKU1, influenza A or influenza B virus infection. P-values for comparing the frequency of respiratory virus detection between the mask intervention were obtained by two-sided Fisher's exact test, and (two-sided) p-values for mask intervention as predictor of log₁₀ virus copies per sample were obtained by an unadjusted univariate Tobit regression model which allowed for censoring at the lower limit of detection of the RT-PCR assay, with significant difference in bold. Undetectable values were imputed as 0.3 log₁₀ virus copies per sample.

Virus type	Droplet particles >5µm			Aerosol particles ≤5µm		
	Without surgical face mask	With surgical face mask	<i>p</i>	Without surgical face mask	With surgical face mask	<i>p</i>
DETECTION OF VIRUS						
	No. Positive / No. Total (%)	No. Positive / No. Total (%)		No. Positive / No. Total (%)	No. Positive / No. Total (%)	
Coronavirus-NL63	0/3 (0)	0/5 (0)	1.00	2/3 (67)	0/5 (0)	0.11
Coronavirus-OC43	2/3 (67)	0/4 (0)	0.14	1/3 (33)	0/4 (0)	0.43
Coronavirus-HKU1	1/4 (25)	0/2 (0)	1.00	1/4 (25)	0/2 (0)	1.00
Influenza A virus	4/19 (21)	1/18 (6)	0.34	6/19 (32)	5/18 (28)	1.00
Influenza B virus	2/6 (33)	0/10 (0)	0.13	2/6 (33)	1/10 (10)	0.52
VIRAL LOAD (log₁₀ virus copies per sample)						
	Median (IQR)	Median (IQR)		Median (IQR)	Median (IQR)	
Coronavirus-NL63	0.3 (0.3, 0.3)	0.3 (0.3, 0.3)	-	3.3 (1.8, 4.0)	0.3 (0.3, 0.3)	0.01
Coronavirus-OC43	2.9 (1.6, 3.1)	0.3 (0.3, 0.3)	0.02	0.3 (0.3, 2.0)	0.3 (0.3, 0.3)	0.21
Coronavirus-HKU1	0.3 (0.3, 0.8)	0.3 (0.3, 0.3)	0.47	0.3 (0.3, 1.6)	0.3 (0.3, 0.3)	0.47
Influenza A virus	0.3 (0.3, 0.3)	0.3 (0.3, 0.3)	0.11	0.3 (0.3, 1.5)	0.3 (0.3, 2.6)	0.82
Influenza B virus	0.3 (0.3, 3.3)	0.3 (0.3, 0.3)	0.04	0.3 (0.3, 4.0)	0.3 (0.3, 0.3)	0.14

Supplementary Table 3. Respiratory virus shedding in nasal swab, throat swab, respiratory droplets and aerosols collected, stratified by days from symptom onset for (a) coronavirus, (b) influenza virus or (c) rhinovirus. For nasal swabs and throat swabs, all infected individuals were included (coronavirus, n = 17; influenza virus, n = 43; rhinovirus, n = 54). For respiratory droplets and aerosols, only infected individuals who provided exhaled breath samples while not wearing a surgical face mask were included (coronavirus, n = 10; influenza virus, n = 23; rhinovirus, n = 36). IQR, interquartile range.

Days since symptom onset	VIRAL LOAD (log ₁₀ virus copies per sample)			
	Median (IQR)			
	Nasal swab	Throat swab	Droplets >5µm	Aerosols ≤5µm
Coronavirus				
0	-	-	-	-
1	6.7 (5.5, 8.2)	3.3 (1.8, 6.8)	0.8 (0.3, 2.9)	1.6 (0.3, 3.7)
2	8.1 (7.4, 8.8)	4.8 (1.8, 5.8)	0.3 (0.3, 0.3)	0.3 (0.3, 1.8)
3	-	-	-	-
Influenza virus				
0	5.6 (5.1, 6.2)	5 (2.9, 5.3)	0.3 (0.3, 0.3)	0.3 (0.3, 0.3)
1	7.3 (6.7, 8.4)	4.4 (3.6, 6.2)	0.3 (0.3, 2.0)	0.5 (0.3, 3.7)
2	6.8 (5.8, 7.5)	4 (2.7, 6.1)	0.3 (0.3, 2.1)	0.3 (0.3, 3.9)
3	5.8 (4.7, 6.3)	1.9 (0.3, 3.8)	0.3 (0.3, 0.3)	0.3 (0.3, 0.3)
Rhinovirus				
0	6.8 (4.2, 9.4)	3.7 (0.3, 7.1)	0.9 (0.3, 1.4)	1.2 (0.3, 2.1)
1	6.9 (6.1, 7.8)	3.3 (2.4, 4.6)	0.3 (0.3, 0.3)	1.8 (0.3, 2.9)
2	6.8 (5.9, 7.3)	3.6 (2.8, 4.6)	0.3 (0.3, 1.4)	0.3 (0.3, 2.9)
3	6.6 (6.1, 7.7)	1.5 (0.3, 4.5)	0.3 (0.3, 1.5)	1.9 (0.8, 2.6)

Supplementary Table 4. Factors associated with coronavirus viral shedding in nasal swab, throat swab, respiratory droplets and aerosols for individuals with symptomatic coronavirus infection. (Two-sided) p-values for individual factor as predictor of log₁₀ virus copies per sample were obtained by an unadjusted univariate Tobit regression model which allowed for censoring at the lower limit of detection of the RT-PCR assay, with significant difference in bold. The model was not applicable for factors where there was only one unique value in either the predictor or outcome, or when the number of observations was less than 2. Only infected individuals who provided exhaled breath samples while not wearing a surgical face mask were included in the analysis (n = 10). 95% CI, 95% confidence interval; -, not applicable.

	Nasal swab		Throat swab		Droplet particle >5µm		Aerosol particle ≤5µm	
	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p
Female	-1.30 (-5.09, 2.48)	0.51	-3.05 (-7.78, 1.68)	0.23	0.81 (-0.98, 2.61)	0.39	-1.11 (-3.66, 1.45)	0.41
Age	0.03 (-0.06, 0.13)	0.51	-0.02 (-0.13, 0.09)	0.69	0 (-0.05, 0.04)	0.91	0 (-0.07, 0.07)	0.95
Chronic medication conditions								
Any	1.20 (-2.09, 4.50)	0.48	-2.06 (-5.76, 1.63)	0.29	-0.93 (-2.43, 0.57)	0.24	-0.47 (-2.81, 1.86)	0.70
Respiratory	-	-	-	-	-	-	-	-
Influenza vaccination								
Ever	-2.10 (-5.22, 1.02)	0.20	-2.5 (-5.54, 0.55)	0.13	-0.5 (-2.05, 1.05)	0.54	-0.71 (-3.03, 1.62)	0.56
Current season	1.36 (-3.73, 6.45)	0.61	-4.12 (-8.89, 0.66)	0.11	-0.72 (-3.19, 1.75)	0.57	-1.48 (-5.16, 2.21)	0.44
Prior season only	-3.52 (-6.73, -0.32)	0.05	-0.86 (-4.73, 3.01)	0.67	-0.25 (-2.05, 1.55)	0.79	-0.09 (-2.78, 2.59)	0.95
Ever smoker	-2.10 (-5.22, 1.02)	0.20	-2.5 (-5.54, 0.55)	0.13	-0.5 (-2.05, 1.05)	0.54	-0.71 (-3.03, 1.62)	0.56
Day(s) since symptom onset	1.36 (-3.73, 6.45)	0.61	-4.12 (-8.89, 0.66)	0.11	-0.72 (-3.19, 1.75)	0.57	-1.48 (-5.16, 2.21)	0.44
History of measured fever ≥37.8°C	-3.52 (-6.73, -0.32)	0.05	-0.86 (-4.73, 3.01)	0.67	-0.25 (-2.05, 1.55)	0.79	-0.09 (-2.78, 2.59)	0.95
Measured fever ≥37.8°C at presentation	-	-	-	-	-	-	-	-
Measured body temperature (°C) at enrolment (Mean, SD)	0.22 (-2.94, 3.37)	0.89	-3.43 (-5.8, -1.06)	0.01	-1.09 (-2.41, 0.23)	0.12	-0.97 (-3.09, 1.15)	0.38
Symptoms at presentation								
Feverishness	2.19 (-0.91, 5.28)	0.18	2.48 (-0.54, 5.50)	0.13	0.48 (-1.03, 2.00)	0.54	0.21 (-2.12, 2.54)	0.86
Cough	-	-	-	-	-	-	-	-
Sore throat	3.16 (-1.63, 7.96)	0.21	4.12 (-0.66, 8.89)	0.11	0.72 (-1.75, 3.19)	0.57	1.48 (-2.21, 5.16)	0.44
Runny nose	-	-	-	-	-	-	-	-
Headache	5.65 (4.01, 7.30)	<0.01	2.73 (-0.8, 6.25)	0.15	0.25 (-1.55, 2.05)	0.79	0.09 (-2.59, 2.78)	0.95
Myalgia	-0.06 (-3.22, 3.10)	0.97	1.66 (-1.42, 4.74)	0.31	-0.01 (-1.47, 1.44)	0.98	-0.43 (-2.60, 1.73)	0.70
Phlegm	2.67 (-0.28, 5.61)	0.09	3.08 (0.31, 5.85)	0.05	0.48 (-1.03, 2.00)	0.54	1.64 (-0.44, 3.71)	0.14
Chest tightness	-	-	-	-	-	-	-	-
Shortness of breath	1.83 (-1.12, 4.78)	0.24	0.63 (-2.78, 4.04)	0.72	-1.09 (-2.41, 0.23)	0.12	-0.37 (-2.55, 1.81)	0.74
Chills	-1.89 (-5.06, 1.28)	0.26	0.83 (-2.56, 4.22)	0.64	0.91 (-0.51, 2.34)	0.23	-0.71 (-3.03, 1.62)	0.56
Sweats	1.39 (-2.38, 5.16)	0.48	1.45 (-2.33, 5.22)	0.46	1.04 (-0.58, 2.66)	0.22	-1.66 (-4.27, 0.95)	0.23
Fatigue	-	-	-	-	-	-	-	-
Vomiting	1.85 (-3.18, 6.88)	0.48	3.38 (-1.26, 8.02)	0.17	2.58 (0.92, 4.24)	0.01	-1.48 (-5.16, 2.21)	0.44
Diarrhea	1.75 (-3.29, 6.80)	0.51	0.51 (-4.63, 5.64)	0.85	-0.72 (-3.19, 1.75)	0.57	1.86 (-1.45, 5.17)	0.29
Number of cough during exhaled breath collection	0.02 (-0.02, 0.05)	0.33	0.03 (-0.03, 0.09)	0.40	0.03 (0.01, 0.05)	0.03	-0.02 (-0.06, 0.03)	0.50

Supplementary Table 5. Factors associated with influenza virus viral shedding in nasal swab, throat swab, respiratory droplets and aerosols for individuals with symptomatic influenza virus infection. (Two-sided) p-values for individual factor as predictor of log₁₀ virus copies per sample were obtained by an unadjusted univariate Tobit regression model which allowed for censoring at the lower limit of detection of the RT-PCR assay, with significant difference in bold. The model was not applicable for factors where there was only one unique value in either the predictor or outcome, or when the number of observations was less than 2. Only infected individuals who provided exhaled breath samples while not wearing a surgical face mask were included in the analysis (n = 23). 95% CI, 95% confidence interval; -, not applicable.

	Nasal swab		Throat swab		Droplets >5µm		Aerosols ≤5µm	
	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p
Female	-0.04 (-0.93, 0.86)	0.94	0.35 (-1.51, 2.22)	0.71	-0.15 (-1.11, 0.82)	0.77	-0.33 (-1.87, 1.22)	0.68
Age	-0.01 (-0.04, 0.02)	0.53	0.05 (-0.01, 0.12)	0.09	0 (-0.03, 0.04)	0.90	0.01 (-0.05, 0.06)	0.85
Chronic medication conditions								
Any	-0.11 (-2.25, 2.03)	0.92	0.94 (-3.62, 5.5)	0.69	1.24 (-1.00, 3.48)	0.28	2.47 (-1.07, 6.02)	0.18
Respiratory	-0.11 (-2.25, 2.03)	0.92	0.94 (-3.62, 5.5)	0.69	1.24 (-1.00, 3.48)	0.28	2.47 (-1.07, 6.02)	0.18
Influenza vaccination								
Ever	0.41 (-0.50, 1.32)	0.39	2.17 (0.43, 3.92)	0.02	0.99 (0.08, 1.91)	0.04	1.59 (0.12, 3.05)	0.04
Current season	0.55 (-1.58, 2.68)	0.62	3.57 (-0.76, 7.90)	0.11	-0.68 (-3.18, 1.81)	0.59	-1.24 (-5.25, 2.77)	0.55
Prior season only	0.33 (-0.62, 1.27)	0.50	1.63 (-0.29, 3.54)	0.10	1.2 (0.29, 2.11)	0.01	1.94 (0.49, 3.39)	0.01
Ever smoker	0.87 (-0.37, 2.12)	0.18	0.63 (-2.13, 3.39)	0.66	0.48 (-0.92, 1.88)	0.50	0.66 (-1.59, 2.92)	0.57
Day(s) since symptom onset	-0.15 (-0.72, 0.43)	0.62	-0.06 (-1.29, 1.17)	0.93	0.03 (-0.61, 0.67)	0.93	0.04 (-0.99, 1.06)	0.95
History of measured fever ≥37.8°C	-2.72 (-3.83, -1.61)	<0.01	-1.2 (-4.36, 1.96)	0.47	-1.28 (-2.97, 0.41)	0.15	-2 (-4.48, 0.48)	0.13
Measured fever ≥37.8°C at presentation	-0.05 (-0.96, 0.85)	0.91	-0.06 (-1.95, 1.83)	0.95	0.61 (-0.33, 1.55)	0.21	0.74 (-0.79, 2.27)	0.35
Measured body temperature (°C) at enrolment (Mean, SD)	0.04 (-0.50, 0.59)	0.88	-0.25 (-1.36, 0.87)	0.67	0.35 (-0.22, 0.92)	0.24	0.37 (-0.55, 1.30)	0.43
Symptoms at presentation								
Feverishness	-0.33 (-1.22, 0.55)	0.46	-1.24 (-3.05, 0.58)	0.19	0.29 (-0.68, 1.26)	0.56	0.19 (-1.37, 1.76)	0.81
Cough	1.46 (0.03, 2.88)	0.05	-1.22 (-4.50, 2.05)	0.47	0.72 (-1.07, 2.50)	0.44	0.17 (-2.59, 2.93)	0.91
Sore throat	0.11 (-0.89, 1.11)	0.83	-1.11 (-3.18, 0.97)	0.30	-0.02 (-1.12, 1.08)	0.98	-0.16 (-1.92, 1.60)	0.86
Runny nose	1.44 (0.45, 2.43)	0.01	1.95 (-0.18, 4.09)	0.08	0.83 (-0.34, 2.00)	0.17	0.99 (-0.90, 2.87)	0.31
Headache	-0.12 (-1.03, 0.78)	0.79	-0.42 (-2.33, 1.48)	0.67	0.06 (-0.93, 1.05)	0.91	-0.2 (-1.78, 1.39)	0.81
Myalgia	-0.27 (-1.27, 0.73)	0.60	0.77 (-1.34, 2.88)	0.48	0.88 (-0.20, 1.96)	0.12	1.6 (-0.11, 3.31)	0.07
Phlegm	1.17 (0.13, 2.22)	0.03	2.81 (0.59, 5.04)	0.02	0.79 (-0.50, 2.08)	0.24	1.43 (-0.63, 3.49)	0.18
Chest tightness	-0.25 (-1.31, 0.81)	0.65	0.29 (-1.97, 2.56)	0.80	0.66 (-0.46, 1.78)	0.26	1.39 (-0.37, 3.14)	0.13
Shortness of breath	0.35 (-0.64, 1.35)	0.49	1.79 (-0.20, 3.78)	0.09	-0.36 (-1.46, 0.75)	0.53	-0.54 (-2.31, 1.23)	0.55
Chills	0.07 (-0.86, 0.99)	0.89	-0.24 (-2.20, 1.71)	0.81	0.38 (-0.63, 1.40)	0.46	0.74 (-0.87, 2.35)	0.37
Sweats	0.16 (-0.79, 1.12)	0.74	0.64 (-1.37, 2.66)	0.53	0.39 (-0.64, 1.42)	0.47	0.48 (-1.18, 2.15)	0.57
Fatigue	0.03 (-1.52, 1.59)	0.97	1.27 (-1.48, 4.01)	0.37	0.75 (-0.72, 2.23)	0.32	1.36 (-1.00, 3.72)	0.26
Vomiting	0.37 (-1.17, 1.91)	0.64	3.01 (-0.06, 6.08)	0.06	-0.72 (-2.50, 1.07)	0.44	-1.3 (-4.16, 1.57)	0.38
Diarrhea	-0.32 (-2.46, 1.82)	0.77	-1.82 (-6.41, 2.77)	0.44	-0.68 (-3.18, 1.81)	0.59	-1.24 (-5.25, 2.77)	0.55
Number of cough during exhaled breath collection	0.01 (-0.03, 0.05)	0.53	0.08 (0.01, 0.16)	0.04	0.04 (0, 0.08)	0.04	0.07 (0, 0.13)	0.04

Supplementary Table 6. Factors associated with rhinovirus viral shedding in nasal swab, throat swab, respiratory droplets and aerosols for individuals with symptomatic rhinovirus infection. (Two-sided) p-values for individual factor as predictor of log₁₀ virus copies per sample were obtained by an unadjusted univariate Tobit regression model which allowed for censoring at the lower limit of detection of the RT-PCR assay, with significant difference in bold. The model was not applicable for factors where there was only one unique value in either the predictor or outcome, or when the number of observations was less than 2. Only infected individuals who provided exhaled breath samples while not wearing a surgical face mask were included in the analysis (n = 36). 95% CI, 95% confidence interval; -, not applicable.

	Nasal swab		Throat swab		Droplets >5µm		Aerosols ≤5µm	
	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p	Estimate (95% CI)	p
Female	-0.81 (-1.71, 0.08)	0.08	0.8 (-0.49, 2.10)	0.23	-0.05 (-0.63, 0.53)	0.87	-1.06 (-1.92, -0.2)	0.02
Age	0.01 (-0.02, 0.04)	0.42	0.01 (-0.04, 0.05)	0.81	-0.02 (-0.04, 0)	0.07	0 (-0.03, 0.04)	0.78
Chronic medication conditions								
Any	0.43 (-0.71, 1.58)	0.46	-0.37 (-2.02, 1.28)	0.66	-0.56 (-1.38, 0.26)	0.18	0.64 (-0.47, 1.74)	0.26
Respiratory	-0.72 (-3.48, 2.04)	0.61	-0.22 (-4.19, 3.74)	0.91	-0.49 (-2.26, 1.28)	0.59	0.92 (-1.75, 3.59)	0.50
Influenza vaccination								
Ever	-0.24 (-1.19, 0.71)	0.63	1.1 (-0.22, 2.41)	0.11	0.05 (-0.56, 0.66)	0.88	-0.59 (-1.52, 0.34)	0.22
Current season	-1.1 (-2.70, 0.51)	0.19	1.19 (-1.12, 3.50)	0.32	-0.51 (-1.77, 0.76)	0.43	-0.67 (-2.31, 0.96)	0.42
Prior season only	0.15 (-0.87, 1.17)	0.78	0.8 (-0.64, 2.23)	0.28	0.2 (-0.44, 0.84)	0.54	-0.41 (-1.41, 0.59)	0.42
Ever smoker	-1.07 (-2.64, 0.49)	0.18	-0.12 (-2.36, 2.13)	0.92	0.22 (-0.77, 1.22)	0.66	0.86 (-0.72, 2.43)	0.29
Day(s) since symptom onset	0.01 (-0.53, 0.55)	0.98	-0.49 (-1.27, 0.29)	0.22	0.1 (-0.23, 0.43)	0.55	0.08 (-0.45, 0.62)	0.75
History of measured fever ≥37.8°C	0.45 (-1.18, 2.09)	0.59	1.09 (-1.48, 3.65)	0.42	-0.85 (-1.74, 0.03)	0.07	-1.92 (-3.11, -0.74)	<0.01
Measured fever ≥37.8°C at presentation	-2.39 (-5.05, 0.26)	0.08	4.08 (0.39, 7.78)	0.03	-0.49 (-2.26, 1.28)	0.59	-1.41 (-4.31, 1.49)	0.35
Measured body temperature (°C) at enrolment (Mean, SD)	-0.3 (-0.96, 0.36)	0.37	1.22 (0.35, 2.08)	0.01	0.01 (-0.41, 0.42)	0.98	-0.27 (-0.93, 0.39)	0.42
Symptoms at presentation								
Feverishness	-0.23 (-1.25, 0.79)	0.66	1.07 (-0.34, 2.49)	0.14	0.28 (-0.33, 0.90)	0.37	-0.62 (-1.61, 0.38)	0.23
Cough	-0.02 (-1.25, 1.20)	0.97	-1.21 (-2.90, 0.49)	0.17	0.17 (-0.58, 0.93)	0.65	0.91 (-0.38, 2.20)	0.17
Sore throat	-0.98 (-2.94, 0.98)	0.33	1.34 (-1.01, 3.69)	0.27	-0.66 (-1.81, 0.49)	0.26	-0.03 (-1.98, 1.92)	0.97
Runny nose	0.72 (-0.71, 2.15)	0.33	0.63 (-1.44, 2.71)	0.55	0.54 (-0.36, 1.45)	0.25	0.56 (-0.87, 1.99)	0.45
Headache	-0.35 (-1.32, 0.61)	0.48	-0.52 (-1.90, 0.86)	0.46	0.22 (-0.39, 0.83)	0.49	0.13 (-0.85, 1.12)	0.79
Myalgia	-0.35 (-1.30, 0.59)	0.47	0.16 (-1.20, 1.53)	0.82	-0.15 (-0.75, 0.45)	0.63	-1.35 (-2.18, -0.53)	<0.01
Phlegm	-0.41 (-1.50, 0.68)	0.47	-1.02 (-2.55, 0.51)	0.20	0.04 (-0.67, 0.75)	0.91	0.49 (-0.65, 1.62)	0.40
Chest tightness	0.74 (-0.69, 2.16)	0.32	-2.19 (-4.19, -0.18)	0.04	-0.22 (-1.12, 0.67)	0.63	-1.26 (-2.69, 0.17)	0.09
Shortness of breath	0.6 (-0.30, 1.50)	0.20	0.83 (-0.46, 2.12)	0.21	0.41 (-0.16, 0.98)	0.17	-0.75 (-1.63, 0.13)	0.10
Chills	-0.31 (-1.33, 0.70)	0.55	-0.67 (-2.08, 0.73)	0.35	0.46 (-0.14, 1.07)	0.13	-0.55 (-1.54, 0.45)	0.29
Sweats	-0.1 (-1.09, 0.90)	0.85	-0.52 (-1.93, 0.89)	0.47	-0.24 (-0.87, 0.39)	0.46	-1.04 (-1.97, -0.11)	0.03
Fatigue	-0.13 (-1.35, 1.09)	0.83	-0.36 (-2.11, 1.38)	0.68	0.34 (-0.47, 1.16)	0.41	-0.94 (-2.10, 0.21)	0.11
Vomiting	-0.88 (-3.63, 1.88)	0.54	1.84 (-2.05, 5.73)	0.36	2.24 (0.81, 3.66)	<0.01	-1.41 (-4.31, 1.49)	0.35
Diarrhea	-0.29 (-1.94, 1.35)	0.73	2.73 (0.56, 4.89)	0.02	1.21 (0.34, 2.09)	0.01	-0.07 (-1.69, 1.56)	0.94
Number of cough during exhaled breath collection	-0.01 (-0.06, 0.03)	0.48	0 (-0.06, 0.06)	0.97	0.02 (-0.01, 0.04)	0.22	0.02 (-0.02, 0.06)	0.36